Upper Extremity Proprioceptive Training

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Abstract: *Proprioception following lower extremity injuries is commonly recommended, but there is little information on proprioception training following upper extremity injuries. No studies have evaluated whether proprioception programs for athletes in open kinetic chain activities (throwing, shot putting) should be different than programs for athletes in closed kinetic chain activities (gymnastics, swimming, kayaking, or rowing). In this paper, we provide a rationale for proprioception training for upper extremity injuries in athletes and the importance of analyzing the athlete's sport and activity for specificity of proprioception exercises. We then discuss one popular proprioception exercise, rhythmic stabilization, and propose several additional upper extremity proprioception exercises, along with instructions for the athletic trainer on how to direct the athlete through these exercises.*

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Proprioception training is an essential part of any rehabilitation program to return an athlete to preinjury performance levels. Special proprioception exercises are a relatively new addition to sport rehabilitation but have been an integral part of programs for patients with brain and spinal cord injuries.[5]

There are two essential parts of proprioception: the "body's ability to vary contractile forces of muscles in immediate response to outside forces"[2] and the "sense that tells the brain which position the limb is in at any moment in time."[15] Exercises for range of motion, muscular strength and endurance, and cardiovascular endurance aid redevelopment of proprioception by contracting muscles and moving joints, but athletes require specific proprioception exercises to regain full musculoskeletal and athletic function.[1]

Recurrent joint instability is either mechanical or functional, existing separately or together. With capsular or ligamentous laxity, the joint is mechanically unstable due to nonfunctional supporting structures. Muscular weakness can also cause mechanical instability since the musculature crossing the joint cannot hold the joint in position. The third cause of instability is lack of proprioceptive feedback, a functional instability, causing an uncoordinated muscular response to motion and/or stress. A functional instability does not necessarily connote a mechanical instability, and muscular weakness does not necessarily cause a functional instability.[8,11,18]

Anatomy

Proprioceptive feedback reaches the central nervous system from receptors located in muscles and joints,[2,3,9,14,16,17] vestibular apparatus in the inner ear,[17] and the eyes.[16] Muscle and joint receptors are stimulated by movements of the musculoskeletal system.[2,3,9,14,16,17] The vestibular apparatus provides information on whole body position and is stimulated when upright body posture changes.[17] The eyes help orient the head and body with respect to the environment. Since athletes must attend to sport-related stimuli when performing, they rely on information from muscle and joint receptors and the vestibular apparatus to balance and maintain body position. When visual stimuli are removed or are distracting, damaged muscle and joint receptors are reeducated to provide accurate positional information to the central nervous system.[10,14,15] Proprioception exercises attempt to simulate sport situations in the rehabilitation setting.

Muscle receptors are comprised of muscle spindles and Golgi tendon organs.[2,16,17] Muscle spindles are special muscle fibers in parallel with regular skeletal muscle fibers.[2,16,17] They occur in larger numbers in "skill" muscles in the hands than in "strength" muscles in the legs and back.[2] Muscle spindles provide information via the gamma feedback loop to the central nervous system. This loop monitors change in muscle length and velocity of contraction,[2,16] providing indirect joint position information.[17] When skeletal muscle is stimulated, muscle spindles are co-activated, maintaining tension. Decreased muscle spindle tension reduces or stops its firing. The gamma feedback loop permits rapid error correction of muscular tension in 30 to 80 ms, while correction through visual stimuli may take as long as 200 ms.[16]

Golgi tendon organs are located in tendons near the musculotendinous junction and in series with the muscle fibers. They monitor muscle tension with firing rate escalating with increased muscle tension. Excessive firing rates from Golgi tendon organs cause a reflex decrease in muscle tension.[2,16,17]

Joint receptors are located in joint capsules, ligaments, fat pads, and periosteum of the various joints of the body.[2,9,14,16,17] As these structures are deformed by motion, joint receptors are stimulated, signaling joint position and movement over the entire range of motion.[17] Joint receptors complement information from muscle spindles and Golgi tendon organs by directly registering joint motion.[16]

No single receptor provides all the information needed by the central nervous system to evaluate posture and body position. Input from muscle and joint receptors, vestibular apparatus, and the eyes is synthesized for total body position information.[17]

Rationale

Proprioception retraining following lower extremity injuries is commonly recommended,[1–3,6,10,12–14] but there is little information on proprioception training following upper extremity injuries, especially in athletes.[4,7,18] No studies have evaluated whether proprioception programs for athletes in open kinetic chain activities, eg, throwing or shot putting, should be different than programs for athletes in closed kinetic chain activities, eg, gymnastics, swimming, kayaking, or rowing.

Injuries requiring surgery and/or periods of immobilization tend to have larger proprioceptive deficits due to time loss and decreased use.[2] Current injury management, therefore, encourages early, protected motion whenever possible.[12] As mentioned earlier, musculoskeletal motion stimulates muscle and joint receptors in the injured area, maintaining a limited neurological response of these receptors.

Rehabilitation programs begin with restoration of range of motion, muscular endurance, and muscular strength. These exercises, in a nonspecific fashion, stimulate joint and muscle proprioceptors in the injured extremity.[2] Proprioceptive neuromuscular facilitation exercises (PNF), by their design, contribute to proprioception while developing range of motion, muscular endurance, and/or muscular strength.[2,4,7,19]

Analyze Activity

The specific activity and sport the athlete is returning to must be analyzed for specificity of proprioception exercises. If athletes normally use the upper extremity in an open kinetic chain fashion, such as throwers in various sports, volleyball players, basketball players, and weight lifters, the proprioception program should emphasize open chain exercises, such as rhythmic stabilization at multiple positions in the range of motion and the first two exercises listed below. If the athlete uses the upper extremity in a closed kinetic chain fashion, as in gymnastics where he/she is weight bearing, or in swimming, canoeing, rowing, or kayaking where the body is moved over the stationary hand (swimming) or extension of the hand (canoeing, rowing, or kayaking), proprioception exercises should be performed in that manner. Such exercises involve balancing or moving on a trampoline, wobble board, or slide board with eyes closed, analogous to lower extremity exercises.[2,3,10,12,15] In contrast to lower extremity proprioception training, closed kinetic chain upper extremity proprioception exercises appear later in the rehabilitation program due to the amount of strength required to support body weight on the injured extremity.

Exercises

Open kinetic chain proprioception exercises begin when range of motion and pain permit. One popular proprioception exercise for the upper extremity is rhythmic stabilization. No other open kinetic chain exercises are reported in the literature. We are proposing several additional upper extremity proprioception exercises. The exercises move from open to closed kinetic chain. If an athlete does not use his/her upper extremity in a closed kinetic chain fashion, the progression finishes with open kinetic chain exercises.

Exercise 1—Rhythmic Stabilization

The athlete positions his/her upper extremity anywhere in its available range of motion and holds an isometric contraction. The athletic trainer provides enough resistance to cause the athlete to react, but not enough to break the isometric contraction.[19] As the athlete progresses, length of time of rhythmic stabilization increases, athletic trainer resistance increases, and amount of contact area between athletic trainer's hands and athlete's upper extremity decreases.

Exercise 2—Mirroring Upper Extremity

Move the uninjured upper extremity passively to various positions in the available range of motion. Ask the athlete to duplicate this position with his/her injured upper extremity, first with eyes open, then closed. If he/she misses the position, he/she opens his/her eyes and actively duplicates the desired position. Concentrate movement on the injured area, ie, focus on shoulder positions for athletes with shoulder pathology, elbow positions for elbow pathology, and so on. Perform 10 to 20 repetitions of varying positions 5 to 10 times daily. Use isokinetic testing equipment with an electrogoniometer for exact joint position measurements, if desired.[18]

Exercise 3—Duplicating Position, Injured Upper Extremity

Move the injured upper extremity passively to a position within its available range of motion, then return it to its resting position. Again, emphasize positions in the injured area. Then, ask the athlete to actively duplicate the movement, first with his/her eyes open, then closed. If he/she misses the position, he/she opens his/her eyes and actively moves to the desired position. Perform 10 to 20 repetitions of varying positions 5 to 10 times daily.

Exercise 4—Double and Single Arm Balancing

Have the athlete balance with both hands on the floor, a wobble board (Fig 1), and finally a trampoline (Fig

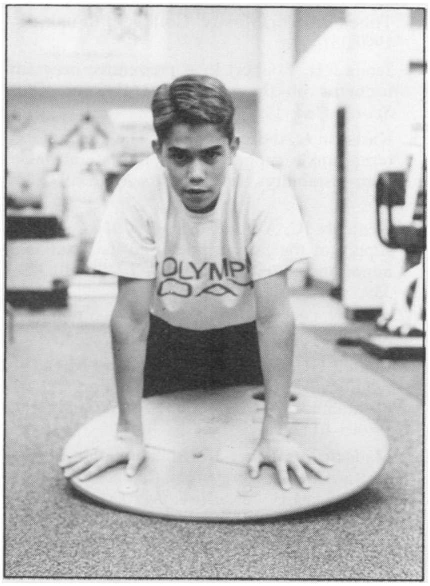

Fig 1.—Eyes open, double arm balance in kneeling push-up position on wobble board.

2). Progress through the following body positions, first with eyes open, then closed. Start in the quadruped position and progress to kneeling push-up, full push-up, and finally feet-elevated (feet level or higher than shoulders) positions. Also, move from balancing on both hands to balancing only on the injured hand. Initially, perform each balance for 15 seconds and gradually extend

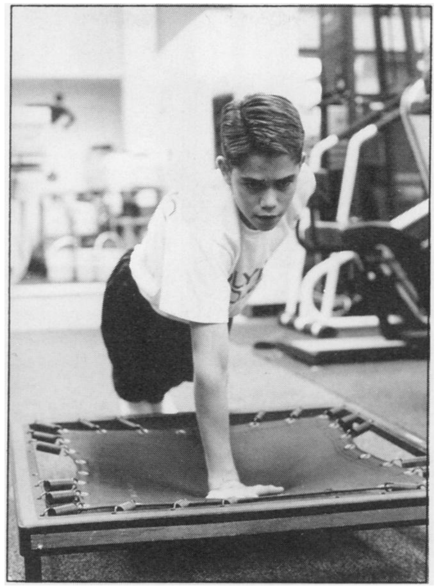

Fig 2.—Eyes open, single arm balance in push-up position on trampoline.

to 60 seconds. Perform 5 to 10 repetitions three to five times daily.

Exercise 5—Fitter®

Have the athlete "stand" on the Fitter (Stack Enterprises, Calgary, Alberta, Canada) on his/her hands. Move through the following body positions first with eyes open, then with eyes closed. Stabilize the Fitter with four resistance cords and position the athlete perpendicular to it. Rock the Fitter from right to left in the frontal plane (Fig 3), then move the athlete parallel to the Fitter and rock it back and forth in the sagittal plane (Fig 4). Next, move the athlete so that he/she is at a 45° angle to the Fitter and rock it on that diagonal. Repeat on the other diagonal. Progress through the four body positions as in Exercise 3. As the athlete progresses, decrease the number of resistance cords on the Fitter, making the platform more unstable. Start with one repetition of 15 seconds and extend to three to five repetitions of 60 seconds each.

Exercise 6—Ball Balancing

Have the athlete balance on his/her hands on a 48-inch Gymnastikball® (Ledragomma, Italy), first with eyes open, then closed (Fig 5). Progress from both hands on one large ball to each hand on separate balls and then to the injured arm on one ball. Also, progress through the four body positions as in Exercise 3. Use a spotter, especially when doing this exercise for the first time or changing body positions, since the athlete may fall off the Gymnastikball®. Start with one repetition of 10 seconds and progress to three to five repetitions of 60 seconds each.

These exercises help redevelop proprioception in athletes with injuries to the upper extremity. The last

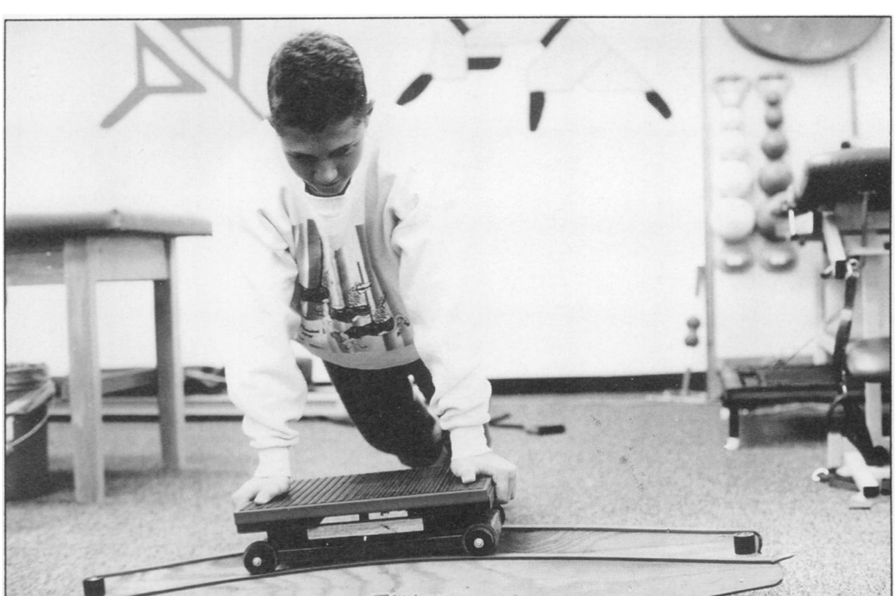

Fig 3.—Eyes open, Fitter® balance in push-up position with platform rocking in the frontal plane.

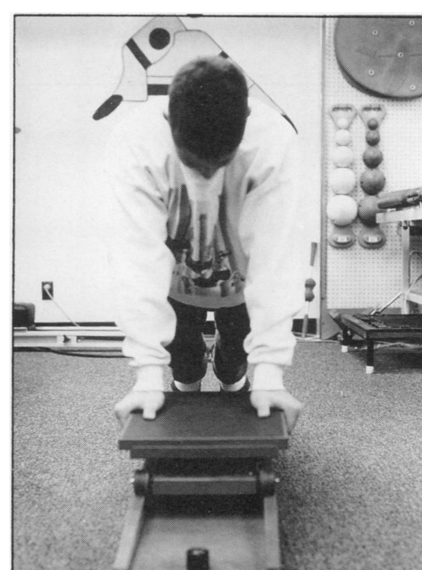

Fig 4.—Fitter® balance in push-up position with platform rocking in the saggital plane.

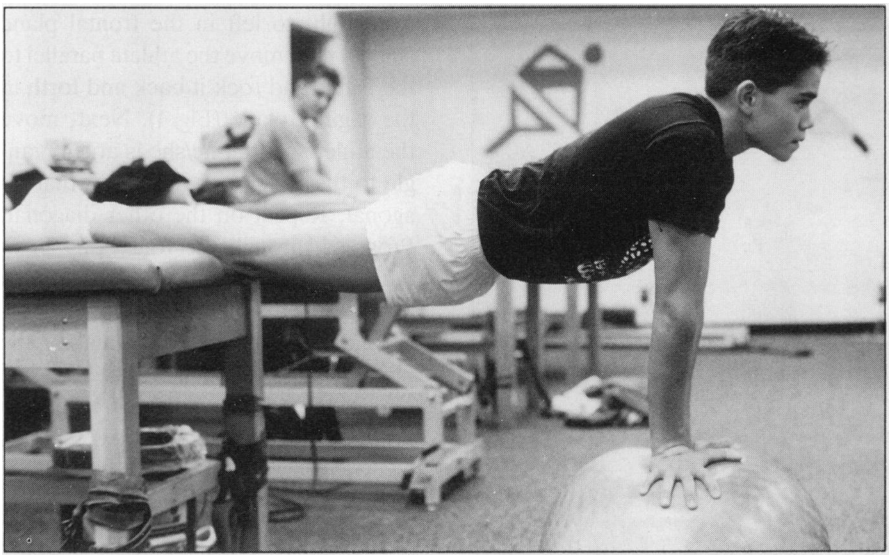

Fig 5.—Eyes open, Gymnastikball® balance in feet-elevated position.

three exercises are especially useful for athletes who use the upper extremity in a closed kinetic chain fashion and become more challenging through the progression from eyes open to eyes closed and through the various body positions.

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References

1. Brunt D, Andersen JC, Huntsman B, Reinhert LB, Thorell AL, Sterling JC. Postural responses to lateral perturbation in healthy subjects and ankle sprain patients. *Med Sci Sport Exerc*. 1992;24:171–176.
2. Day RW, Wildermuth BP. Proprioceptive training in rehabilitation of lower extremity injuries. In: Grana WA, Lombardo JA, Sharkey BJ, Stone JA, eds. *Advances in Sport Medicine and Fitness*. Chicago, IL: Year Book; 1988:241–257.
3. Derscheid GL, Brown WC. Rehabilitation of the ankle. *Clin Sports Med*. 1985;4:527–544.
4. Dilorenzo CE, Parkes JC, Chmelar RD. Importance of shoulder and cervical dysfunction in etiology and treatment of athletic elbow injuries. *J Orthop Sport Phys Ther*. 1990;11:402–409.
5. Griffin JW. Use of proprioceptive stimuli in therapeutic exercise. *Phys Ther*. 1974;54:1072–1079.
6. Hunter SL. Rehabilitation of ankle injuries. In: Prentice WE, ed. *Rehabilitation Techniques in Sports Medicine*. St. Louis, MO: Times Mirror/Mosby College Publishing; 1990:331–341.
7. Janda DH, Loubert P. A preventive program focusing on the glenohumeral joint. *Clin Sports Med*. 1991;10:955–971.
8. Karlsson J, Andreasson GO. The effect of external ankle support in chronic lateral ankle joint instability. *Am J Sports Med*. 1992;20:257–261.
9. Kennedy JC, Alexander IJ, Hayes KC. Nerve supply of the human knee and its functional importance. *Am J Sports Med*. 1982;10:329–335.
10. Kulund DN. *The Injured Athlete*. Philadelphia, PA: JB Lippencott; 1982:527–528.
11. Lentell GL, Katzman LL, Walters MR. The relationship between muscle function and ankle stability. *J Orthop Sport Phys Ther*. 1990;11:605–611.
12. Maddalo A, Walter JF. Rehabilitation of foot and ankle linkage system. In: Nicholas JA, Hershman EB, eds. *The Lower Extremity and Spine in Sports Medicine*. St. Louis, MO: The CV Mosby Company; 1986:560–583.
13. Markey KL. Functional rehabilitation of the anterior cruciate ligament deficient knee. *Sports Med*. 1991;12:407–417.
14. Markey KL. Rehabilitation of the anterior cruciate ligament deficient knee. *Clin Sports Med*. 1985;4:513–526.
15. Riehl R. Rehabilitation of lower leg injuries. In: Prentice WE, ed. *Rehabilitation Techniques in Sports Medicine*. St Louis, MO: Times Mirror/Mosby College Publishing; 1990:316–330.
16. Sage GH. *Motor Learning and Control: A Neuropsychological Approach*. Dubuque, IA: Wm C Brown Publishers; 1984:178–179, 214–217.
17. Schmidt RA. Motor Learning Performance. Champaign, IL: Human Kinetics Books; 1991:47–48.
18. Smith RL, Brunolli J. Shoulder kinesthesia after anterior glenohumeral joint dislocation. *J Orthop Sport Phys Ther*. 1990;11:507–513.
19. Voss DE, Ionta MK, Myers BJ. *Proprioceptive Neuromuscular Facilitation: Patterns and Techniques*. Philadelphia: Harper & Row, Publishers; 1985;302–303.